SILICA-RICH IGNEOUS RIMS AROUND MAGNESIAN CHONDRULES IN CR CARBONACEOUS CHONDRITES: EVIDENCE FOR FRACTIONAL CONDENSATION DURING CHONDRULE FORMATION. A. N. Krot[1*], G. Libourel[2], C. A. Goodrich[1], M. I. Petaev[3], and M. Killgore[4], [1]Hawai'i Institute of Geophysics and Planetology, School of Ocean and Earth Science and Technology, University of Hawai'i at Manoa, Honolulu, HI 96822, USA (sasha@higp.hawaii.edu). [2]CRPG-CNRS 15, Rue Notre-Dame des Pauvres BP20 54501 Vandoeuvre les Nancy, France. [3]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA. Southwest Meteorite Laboratory, PO BOX 95, Payson, AZ 85547, USA.

Introduction: The CR (Renazzo-type) carbonaceous chondrites are among the most pristine meteorites, and therefore, study of their high-temperature components (CAIs, AOAs, chondrules) can potentially provide important information on physico-chemical conditions in the early solar nebula [1, 2]. The CR chondrites are characterized by the presence of large concentrically-zoned (layered) Type I chondrules which may have recorded evolution of solar nebula materials in the region of CR chondrule formation. It was recently shown [3, 4] that the outermost layers around Type I chondrules in CR chondrites commonly have a high abundance of a silica phase, suggesting significant Si/Mg fractionation in the CR chondrule-forming region. Here, we characterize the mineralogy and petrology of these silica-rich rims, and discuss their origins and implications for chondrule formation in general.

Results: The outer portions of many Type I ($Fa_{<5}$, $Fs_{<5}$) porphyritic olivine, porphyritic olivine-pyroxene, and porphyritic pyroxene chondrules from the CR chondrites El Djouf 001, EET87747, EET87770, EET92042, EET92147, EET96286, GRA95229, MAC87320, MET00426, NWA721, PCA91082, QUE99177, and Temple Bar consist of silica-rich igneous rims (SIR); no silica was found in igneous rims around chondrules from Renazzo and Al Rais. The host chondrules are typically layered and consist of a porphyritic core (which may itself be zoned with pyroxene phenocrysts concentrated in a mantle around olivine) surrounded by a coarse-grained, low-Ca pyroxene-rich igneous rim (Fig. 1). SIR are sulfide-free and consist of igneously-zoned low-Ca and high-Ca pyroxenes ($Fs_{1-5}Wo_{0.2-47}$), glassy mesostasis, FeNi-metal nodules, and a silica phase (nearly pure SiO_2). The high-Ca pyroxenes in these rims are enriched in Cr_2O_3 (up to 3.5 wt%) and MnO (up to 4.4 wt%) and depleted in Al_2O_3 and TiO_2 relative to those in the host chondrules, and contain detectable Na_2O (up to 0.2 wt%). Mesostases show systematic compositional variations: SiO_2, Na_2O, K_2O and MnO contents increase, whereas CaO, MgO, Al_2O_3 and Cr_2O_3 contents decrease from chondrule core, through pyroxene-rich igneous rim, to SIR (Fig. 2); FeO content remains nearly constant. FeNi-metal grains in SIR are depleted in Ni and Co relative to those in the host chondrules. The absence of silica in igneous rims around chondrules in Renazzo and Al Rais is probably due to their higher degrees of aqueous alteration compared to other CR chondrites.

Discussion: The presence of sulfide-free SIR around sulfide-free Type I chondrules from CR chondrites suggests that these chondrules formed at high (>800 K) ambient nebular temperatures and escaped remelting at lower ambient temperatures. This implies that CR chondrules belong to an early generation. The very high abundance of silica in some of the SIR, their metal-poor nature, and the absence of dusty olivine or pyroxene grains are inconsistent with the reduction of ferromagnesian silicates being a viable mechanism for the formation of the SIR. Crystallization calculations for melts with bulk compositions corresponding to those of chondrules surrounded by SIR show that fractional crystallization of the chondrules cannot explain the origin of SIR. We suggest that SIR may have formed either by gas-solid condensation of silica-rich materials onto chondrule surfaces and subsequent incomplete melting [3], or by direct $SiO_{(gas)}$ condensation into chondrule melts [5]. In either case, the condensation occurred from a fractionated nebular gas enriched in Si, Na, K, Mn, and Cr. The fractionation of these lithophile elements could be due to isolation (in the chondrules) of the higher temperature condensates from reaction with the nebular gas [3, 6] and/or to evaporation-recondensation of these elements during chondrule formation; the latter is consistent with the inferred evaporation-recondendation of siderophile elements (Pd, Fe, Cu, Au) during Type I chondrule formation in CR chondrites [7, 8]. The very large Si/Mg fractionations in the SIR could have resulted from preferential isolation of forsteritic olivine into the host chondrules [3, 9]. This mechanism, and the observed increase in pyroxene/olivine ratio towards the peripheries of most Type I chondrules in carbonaceous and ordinary chondrites, may explain the origin of olivine-rich and pyroxene-rich Type I chondrules in general. It remains to be shown whether gas-melt condensation, or gas-solid condensation followed by melting, played the major role in defining bulk compositions of Type I chondrules.

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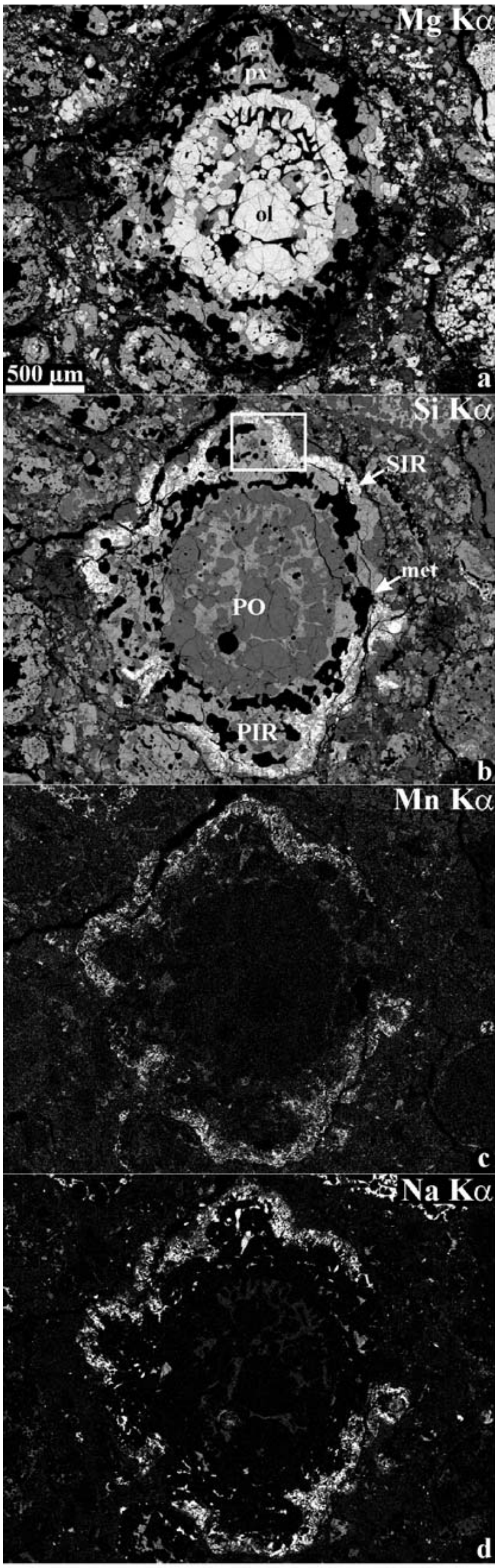

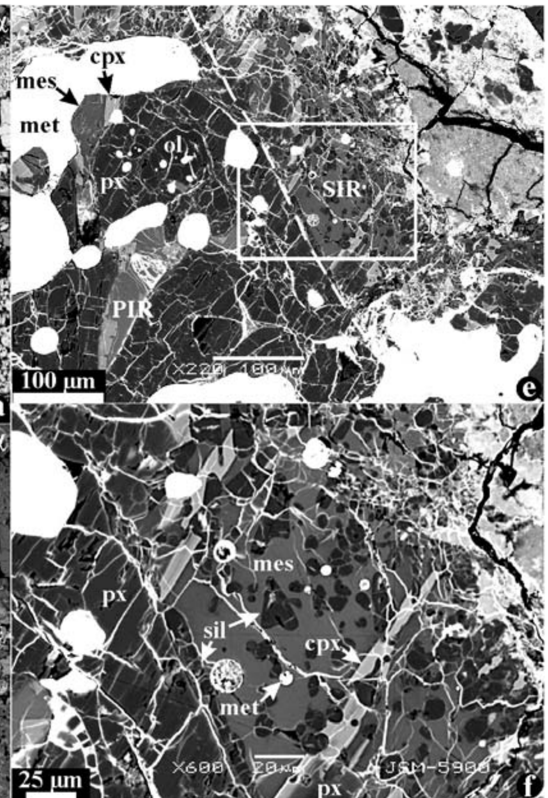

Fig. 1. X-ray elemental maps in Mg (a), Si (b), Na (c), and Mn Kα (d) and BSE images (e, f) of a POP chondrule surrounded by the pyroxene-rich igneous rim (PIR) and SIR. cpx = high-Ca pyroxene, mes = mesostasis, met = FeNi-metal, ol = olivine, px = low-Ca pyroxene, sil = silica. The SIR is enriched in Na and Mn relative to the PIR and chondrule core.

Fig. 2. Compositions of glass in melt inclusions in olivine phenocrysts (incl), and mesostases of a chondrule core (chd), PIR, and SIR.